

or reflected at the surfaces of any number of media bounded by cylindrical surfaces in the most general sense (including, of course, plane as a particular case), the generating lines of which are parallel, and for brevity's sake will be supposed vertical, and if α be the altitude of the ray in air, α' , α'' , . . . , its altitudes in the media of which the refractive indices are μ' , μ'' , . . . , then

(1) The successive altitudes will be determined by the equations

$$\sin \alpha = \mu', \sin \alpha' = \mu'', \sin \alpha'' = \dots,$$

just as if the ray passed through a set of parallel plates.

(2) The course of the horizontal projection of the ray will be the same as would be that of an actual ray passing through a set of media of refractive indices $\frac{\mu' \cos \alpha'}{\cos \alpha}$, $\frac{\mu'' \cos \alpha''}{\cos \alpha}$, . . . instead of μ' , μ'' , ... As $\alpha' < \alpha$, the fictitious index is greater than the actual, and therefore the deviation of the projection is increased by obliquity.

These two propositions, belonging to common optics, place the justice of Mr. Grubb's conclusions in a clear light.—April 30, G. G. STOKES.]

May 7, 1874.

WILLIAM SPOTTISWOODE, M.A., Treasurer and Vice-President, in the Chair.

In pursuance of the Statutes, the names of the Candidates recommended for election into the Society were read from the Chair as follows :—

Isaac Lowthian Bell, F.C.S.
W. T. Blanford, F.G.S.
Henry Bowman Brady, F.L.S.
Thomas Lauder Brunton, M.D.,
Sc.D.
Prof. W. Kingdon Clifford, M.A.
Augustus Wollaston Franks, M.A.
Prof. Olaus Henrici, Ph.D.
Prescott G. Hewett, F.R.C.S.

John Eliot Howard, F.L.S.
Sir Henry Sumner Maine, LL.D.
Edmund James Mills, D.Sc.
Rev. Stephen Joseph Perry,
F.R.A.S.
Henry Wyldbore Rumsey, M.D.
Alfred R. C. Selwyn, F.G.S.
Charles William Wilson, Major
R.E.

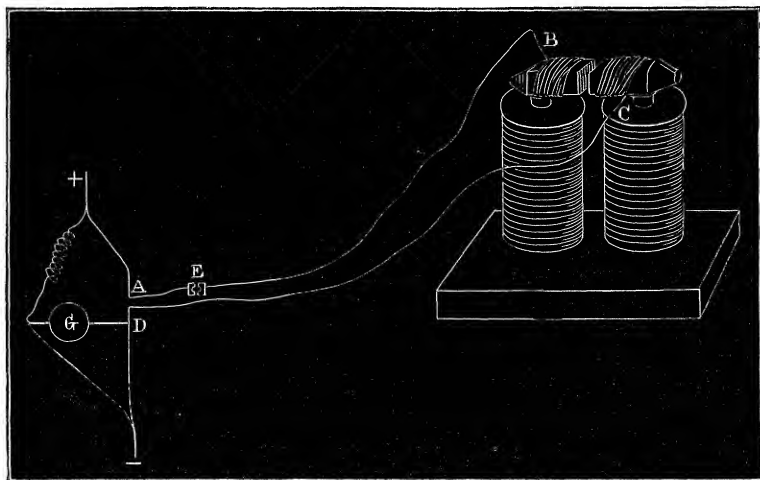
The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

I. "Preliminary Experiments on a Magnetized Copper Wire."

By Professor BALFOUR STEWART, LL.D., F.R.S., and ARTHUR SCHUSTER, Ph.D. Received March 30, 1874.

1. The following experiments were made in the Physical Laboratory of Owens College, Manchester. The copper wire employed (A B C D,



see fig.) was found to contain no perceptible trace of iron, nor was it sensibly magnetic, behaving quite in a neutral manner when tested by the highest magnetic power at our disposal. It was covered with gutta percha. The diameter of the wire was 0.0487 inch. The wire was wound fifty-three times, in one direction, round the poles of a powerful electromagnet, the length of wire encircling these poles being about twelve metres. The direct distance of the magnet from the galvanometer, G, was about twelve metres.

A Wheatstone bridge was employed, and a very delicate Thomson's reflecting galvanometer by Elliott Brothers, of which the resistance was 5540 B.-A. units. A circuit-breaker was placed in the circuit at E, close to the bridge. On some occasions, we used one consisting of a solid key, which might be removed, thus breaking the circuit; but, on other occasions, a fluid or mercurial circuit-breaker was employed.

When the left-hand pole of the electromagnet (see fig.) was made north the arrangement was called (1), and when the other pole was made north the arrangement was called (2). It will thus be seen, from the figure, that the current went round the magnet in the same direction as the molecular currents of arrangement (2).

Experiments were made at intervals of two minutes; and, on each occasion, the current was allowed to pass through the bridge for ten

seconds, the measurement being taken by the first swing of the galvanometer, which lasted for about eight seconds. Three cells of Grove's battery were used for producing this current; but, on the other hand, six similar cells were employed for magnetizing the electromagnet. The arrangements for magnetizing are not shown in the figure. The distance of the magnet was too great to affect the galvanometer-needle so as to alter its sensibility, the average deflection causing a difference in the zero of about four divisions of the scale.

2. In the first experiments made, the key at E (see fig.) was not taken out before the magnetism was put on or off, in consequence of which the induction-current, due to the wire coiled round the magnet, affected the galvanometer on these occasions; but, after December 12th, the key was taken out, so that no induction-current passed.

The following is a specimen of the observations made:—

December 17, 1873.

Time of putting on current.	Whole deflection observed (increasing deflection denotes increasing resistance in A B C D).	Condition of magnet.
11 ^h 11 ^m	312	off
13	317	off
15	311	off
17	345	(1)
19	328	off
21	306	(1)
23	303	off
25	293	(1)
27	300	off
29	290	(1)
31	307	off
33	283	(1)
35	292	off
37	288	(1)
39	302	off
41	292	(1)
43	309	off

It will be seen from this experiment that the *first effect* of putting on the magnetism was a marked increase of resistance; but, with this exception, the resistance, when the magnetism was on, was less than the mean of the two resistances on both sides of it, representing the magnetism off.

3. The arrangement remained untouched, as far as we know, from December 15, when it was finally made, until December 19, when the experiments were interrupted during the Christmas holidays; and in all

cases the *first effect* of putting on the magnetism was a marked increase of resistance. For instance, we have—

Date.	First off.	On first effect.	Second off.
Dec. 16	0	+36 on (2)	+ 3
„ 17	0	+34 on (1)	+17
„ 18	0	+54 on (1)	+24
„ 19	0	+33 on (1)	—18

It was soon seen that this *first effect* had some reference to the time elapsing since the last experiments were made. For instance, in the above Table, we see for December 18th a marked increase of resistance when the magnet was first put on; but, on the afternoon of that day, the experiments were repeated, and there was no apparent increase of resistance in this *first effect*. Next, with regard to the *average effect*: on Dec. 16th, 17th, and 18th, this *average effect* of magnetism was a decrease of resistance; but on Dec. 19th there was an apparent increase of resistance when the magnetism was on. We cannot say that nothing had been done to the arrangement between the 18th and 19th of December that might account for this change; but whatever was done must have escaped our recollection. Undoubtedly a good many experiments were made during the time between the 15th and 19th of December, and the direction of the magnetism was frequently changed. This curious anomaly, occurring unexpectedly, induced us to limit our future experiments to a definite set each day.

4. The experiments were resumed on January 7th, the arrangement having remained untouched during the holidays. From this date until January 10th inclusive, the key was taken out before beginning experiments in the morning: there was no peculiar *first effect*; while, on the other hand, an *average effect* denoting a decrease of resistance came out very prominently. On January 12th and 13th the key was only taken out before magnetizing, and on these occasions the *first effect*, denoting increased resistance, was sufficiently marked.

Our method of procedure was varied in the above manner up to January 27th; and it was invariably found that, whenever the key was taken out before commencing experiments, there was no *first effect*; but when it was kept in until before magnetizing, this *first effect* was sufficiently marked. These experiments concur in proving that the *first effect* has some reference to the previous treatment of the wire; but they do not prove that it is at the same time connected with the putting on of the magnetism. To determine this point we made a set of experiments on January 22nd, 26th, and 27th. When the current had become constant the key was taken out, but the magnetism was not put on; and on these occasions there was no *first effect* of the current upon itself in the direction of increased resistance, but rather in the opposite direction. It thus appears that the *first effect* which increases the resistance has not

only reference to the previous treatment of the wire, but depends also upon the magnetism being put on.

This result is confirmed by experiments made previous to Dec. 12th, in which the key was not taken out at all. For instance, we have on Dec. 9th,

First off.	On first effect.	Second off.
0	+54	+45

We have hitherto only spoken of the *first effect* obtained after January 7th; we now come to the *average effect*. From January 7th to January 27th inclusive, the magnetism was always put on in the direction (1), and the *average effect* invariably denoted a decrease of resistance when the magnetism was on.

5. On January 28th the magnetism was reversed; the effect during this day was very irregular. On January 29th, 30th, 31st, and February 2nd the key was left in until before magnetization. The *first effect* was now extremely large; but it was suspected that, during these experiments, the contact of the key was not very good.

On January 29th the *average effect* denoted a decrease of resistance, but on January 30th, 31st, February 2nd, 4th, 6th, the *average effect* denoted an increase of resistance.

6. From February 6th until February 11th the wires were left broken; on February 11th there was a very slight *first effect* in the direction of increased resistance, and a slight *average effect* in the direction of decreased resistance. On February 12th a mercury interruptor was used instead of a metal key, both the wires being broken by it, and its use was continued until February 18th. The interruptor was left in over night and the current was only broken before magnetization, but no *first effect* was observed.

From February 19th to February 26th one wire only was broken by the fluid interruptor; nevertheless there was no *first effect*.

On February 12th, when the fluid interruptor was first employed, there was a very small *average effect* in the direction of increased resistance; but, in all the experiments afterwards, this *average effect* was in the direction of decreased resistance. The magnetism had been in the direction (2) from January 28th; but, during the experiment of February 25th, it was reversed and retained in this condition through the experiment of February 26th, without appearing to affect the results.

7. From these experiments we may perhaps conclude as follows:—

In the *first place*, there is a *first effect* in the direction of increased resistance which appears to have reference to three things—namely, the previous state of the wire, the solidity of the circuit, and its magnetization.

In the *second place*, we have an *average effect*, of which the normal state appears to denote a decreased resistance while the magnetism is on, without reference to the direction of the magnetism.

In the *third place*, when, in a solid circuit, the direction of the magnetism has been recently changed, there appears to be a temporary reversal of the average effect, which appears, at first, as an increase of resistance. Besides the evidence herein detailed, we have other evidence in favour of the third conclusion; for in some preliminary experiments, in which we frequently reversed the poles, we found an increase of resistance when the magnetism was on. We have given, in a Table appended to this paper, a synopsis of our various experiments.

8. We are led to conclude, from other experiments besides these, that the effect of the magnetism is not merely confined to the part of the copper wire wound round the poles, but is propagated all along the wire. On December 2nd, for instance, the current was passed through the wire, the galvanometer being joined as a secondary circuit. The main current was therefore measured.

The deflections were as follows:—

297	.....	off	300	.....	off
300	.....	(1)	302	.....	(1)
297	.....	off	301	.....	off
300	.....	(1)			

This shows an average strengthening of the current, equal to about one two-hundredth part of the whole. Were this strengthening due to merely the change of resistance of that part of the wire wound round the poles, the effect, as measured by the much more delicate arrangement of Wheatstone's bridge, would be much larger than was actually observed.

9. Allusion was made in article 7 to some preliminary experiments, in which increased resistance was observed when the magnetism was put on (1) and (2) alternately. Similar experiments were made, giving the same result with a piece of coke and graphite, which were placed between the poles of the magnet.

10. We have also some evidence that a copper wire, one end of which is wound round the pole of the magnet, changes its position in the electromotive series. Two copper wires were dipped into dilute nitric acid and connected with the galvanometer. A weak current passed through the galvanometer owing to a slight difference in the copper wires, one of which was also connected with the copper wire wound round the magnet. When the magnet was on, the current, as a rule, changed in intensity; but the effect was small, and the difficulty of having two copper wires which, when joined together and dipped into nitric acid, give a current sufficiently weak and constant, prevented us from getting any decided results.

11. In conclusion we have to state that we regard these results which we have ventured to bring before the Royal Society as preliminary, the correctness of which will, we trust, be confirmed by the further experiments which it is our intention to make.

Date.	Nature of Experiment.	Value of first effect.	Number of observations.	Mean effect, excl. of first effect (— denote decrease of resistance).
1873.				
Dec. 17.	Metal key left in over night taken out before magnetism was put on (1)	off. on. off. 0+34+17	15	— 14
„ 18.	Metal key left in over night taken out before magnetism was put on (1)	0+54+24	30	— 9
„ 19.	Metal key left in over night taken out before magnetism was put on (1)	0+33—18	15	+21
1874.				
Jan. 7.	The key was taken out before beginning the experiments in the morning	No first effect.	15	—17
„ 8.	The key was taken out before beginning the experiments in the morning	Ditto	15	—19
„ 9.	The key was taken out before beginning the experiments in the morning	Ditto	15	—13
„ 10.	The key was taken out before beginning the experiments in the morning	Ditto	15	—20
„ 12.	The key was not taken out until before magnetizing	0+47+18	15	—18
„ 13.	The key was taken out (same as Jan. 7)	No first effect.	Irregular	action.
„ 14.	The key was not taken out (same as Jan. 12) ..	0+3—6	15	—19
„ 15.	Ditto	0+17+11	15	— 2
„ 16.	The key was taken out (same as Jan. 7)	No first effect.	15	—67
„ 17.	The key was not taken out (same as Jan. 12) ..	0+28+119	15	—22
„ 20.	The connexions had been broken since Jan. 17 ..	No first effect.	15	—44
„ 21.	The key was taken out (same as Jan. 7)	0+7+1	15	— 9
„ 22.	When the current was constant the key was taken out, but the magnet was not put on before the current had again become constant.....	No first effect.	15	—13
„ 24.	The key had been left out since Jan. 22	Ditto	15	—11
„ 26.	Same as Jan. 22	Ditto	15	—33
„ 27.	Ditto	Ditto	15	—23
„ 28.	The magnet was put on (2) from this day until Feb. 25 .....	.....	.....	.....
„ 29.	The magnet was put on (2), key left in (same as Jan. 12)	0+102+47	15	—23
„ 30.	The magnet was put on (2), key left in (same as Jan. 12)	0+219	15	+25
„ 31.	The magnet was put on (2), key left in (same as Jan. 12)	0+137+161	15	+16
Feb. 2.	The magnet was put on (2), key left in (same as Jan. 12)	0+ 47+84	15	+11
„ 3.	.....	.....	.....	.....
„ 4.	The key was taken out and put in after several offs, same as Jan. 22.....	No first effect.	15	+31
„ 5.	.....	.....	.....	.....
„ 6.	The key was taken out (same as Jan. 22)	No first effect.	15	+ 3
„ 11.	.....	0+7+3	15	— 3
„ 12.	A mercury interruptor was used instead of metal key	No first effect.	31	+ 3
„ 13.	The mercury interruptor was kept in over night	Ditto	15	—11
„ 14.	The mercury interruptor was kept in over night	Ditto	15	—36
„ 16.	New mercurial contact breaker from Elliott Brothers used	Ditto	15	—18
„ 17.	Ditto key left in (same as Jan. 12)	Ditto	15	— 5
„ 18.	Ditto Ditto	Ditto	15	— 7
„ 19.	One wire only was broken	0+11+16	15	— 2
„ 20.	One wire only was broken, key left in (same as Jan. 12)	No first effect.	15	—13
„ 22.	One wire only was broken, key left in (same as Jan. 12)	Ditto	17	—12
„ 24.	One wire only was broken, key left in (same as Jan. 12)	Ditto	17	— 8
„ 25.	One wire only was broken, magnet on (1)	Ditto	15	— 4

REMARKS.

Dec. 18, 1873. For a second series of 15 on this day no first effect was found.

Jan. 15, 1874. There was a sudden change of the current during the experiments, to which the unusually small effect is most likely due.

Jan. 16. There was a sudden change of the current during the experiments, to which the unusually large effect is most likely due.

Jan. 17. There was an irregularity at the beginning of the experiment.

Jan. 20. Action somewhat irregular.

Jan. 22. There seemed to be a first effect of the current on itself in the opposite direction, 0—14—9.

Jan. 26. There seemed to be again a first effect in opposite direction, 0—47—57.

Jan. 27. Ditto Ditto 0—17—17.

Jan. 28. The action was very irregular.

Jan. 29. It is suspected that during the experiments from Jan. 29 to Feb. 12 the contact at the key was not very good.

Feb. 3. The action was very irregular.

Feb. 4. There seemed to be two first effects of the current upon itself in the direction of increased resistance.

Feb. 5. The action was very irregular.

Feb. 6. There seemed to be a first effect of decreased resistance of current upon itself.

Feb. 11. The wires had been broken since Feb. 6th.

Feb. 12. One of the wires had got between the pole and the core of the magnet.

Feb. 24. After the first on (2) the magnet was always put on (1).

II. "Note on some Winter Thermometric Observations in the Alps." By E. FRANKLAND, F.R.S.

During the past winter, I spent a fortnight at the village of Davos, Canton Graubünden, Switzerland, and had thus an opportunity of experiencing some of the remarkable peculiarities of the climate of the elevated valley (the Prättigau) in which Davos is situated. The village has of late acquired considerable repute as a climatic sanitarium for persons suffering from diseases of the chest. So rapidly has its reputation grown, that while in the winter of 1865–66 only eight patients resided there, during the past season upwards of three hundred have wintered in the valley.

The summer climate of Davos is very similar to that of Pontresina and St. Moritz, in the neighbouring high valley of the Engadin—cool and rather windy; but so soon as the Prättigau and surrounding mountains become thickly and, for the winter, permanently covered with snow, which usually happens in November, a new set of conditions come into play and the winter climate becomes exceedingly remarkable. The sky is, as a rule, cloudless or nearly so; and, as the solar rays, though very powerful, are incompetent to melt the snow, they have little effect upon the temperature, either of the valley or its enclosing mountains; consequently there are no currents of heated air; and, as the valley is well sheltered from more general atmospheric movements, an almost uniform calm prevails until the snow melts in spring.

